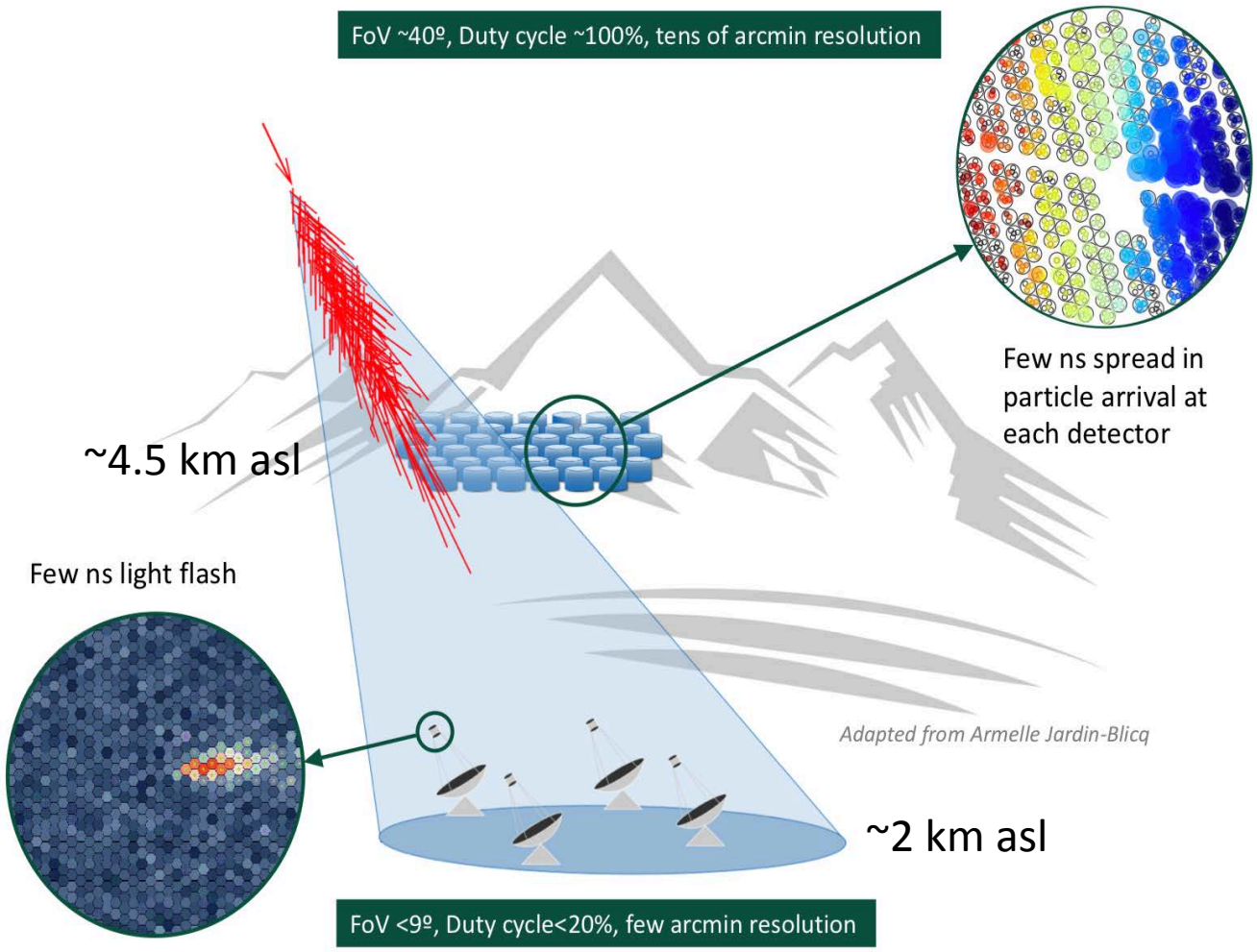
SWGO

the Southern Wide-Field Gamma-ray Observatory

Alessandro De Angelis, INFN Padova, 25 June 2019

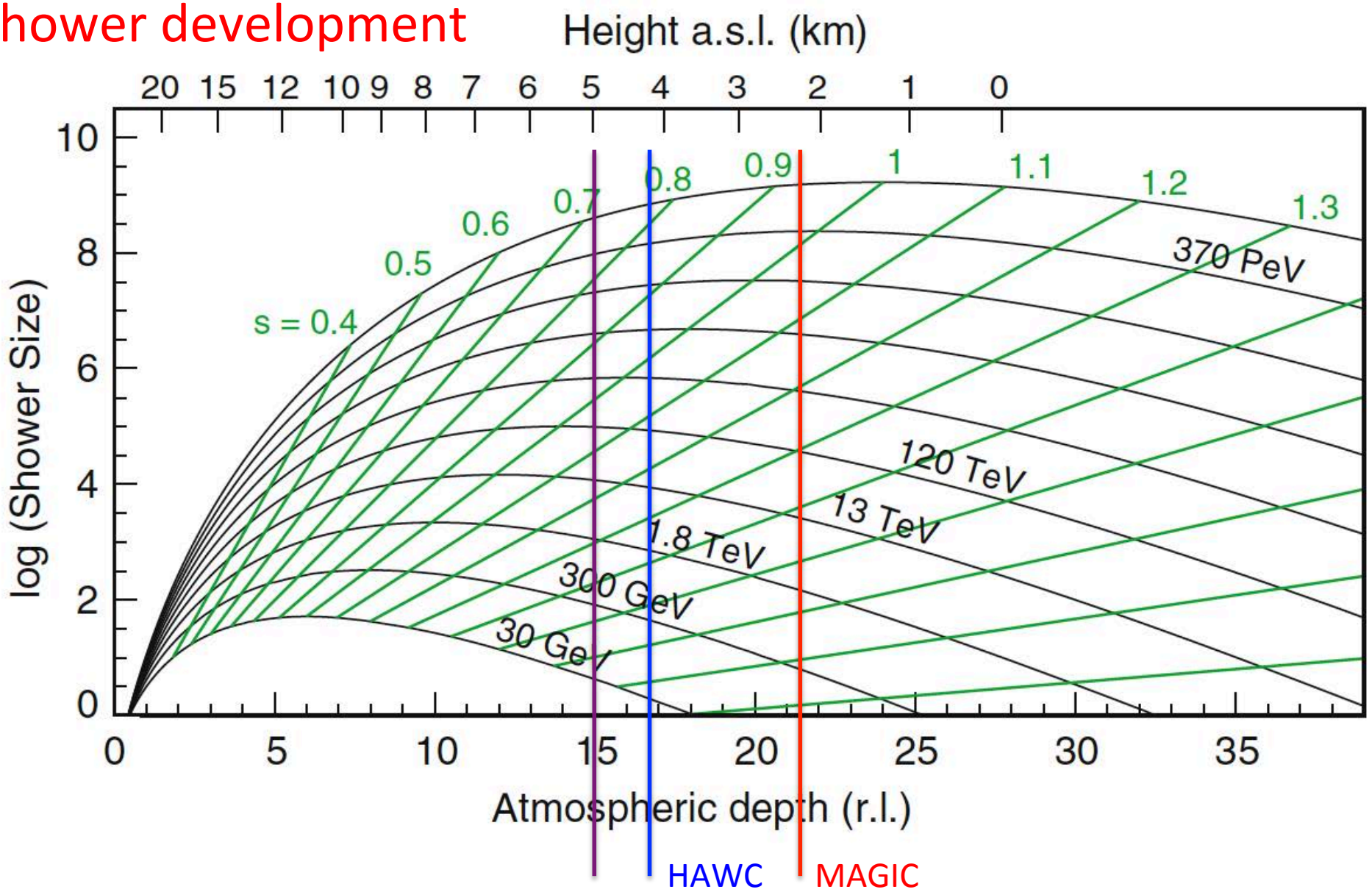
Detecting gamma-ray atmospheric showers



Two techniques

- Cherenkov (high sensitivity & accuracy, small Field of View, at night)
- EAS arrays (worse sensitivity & accuracy, large FoV, always)

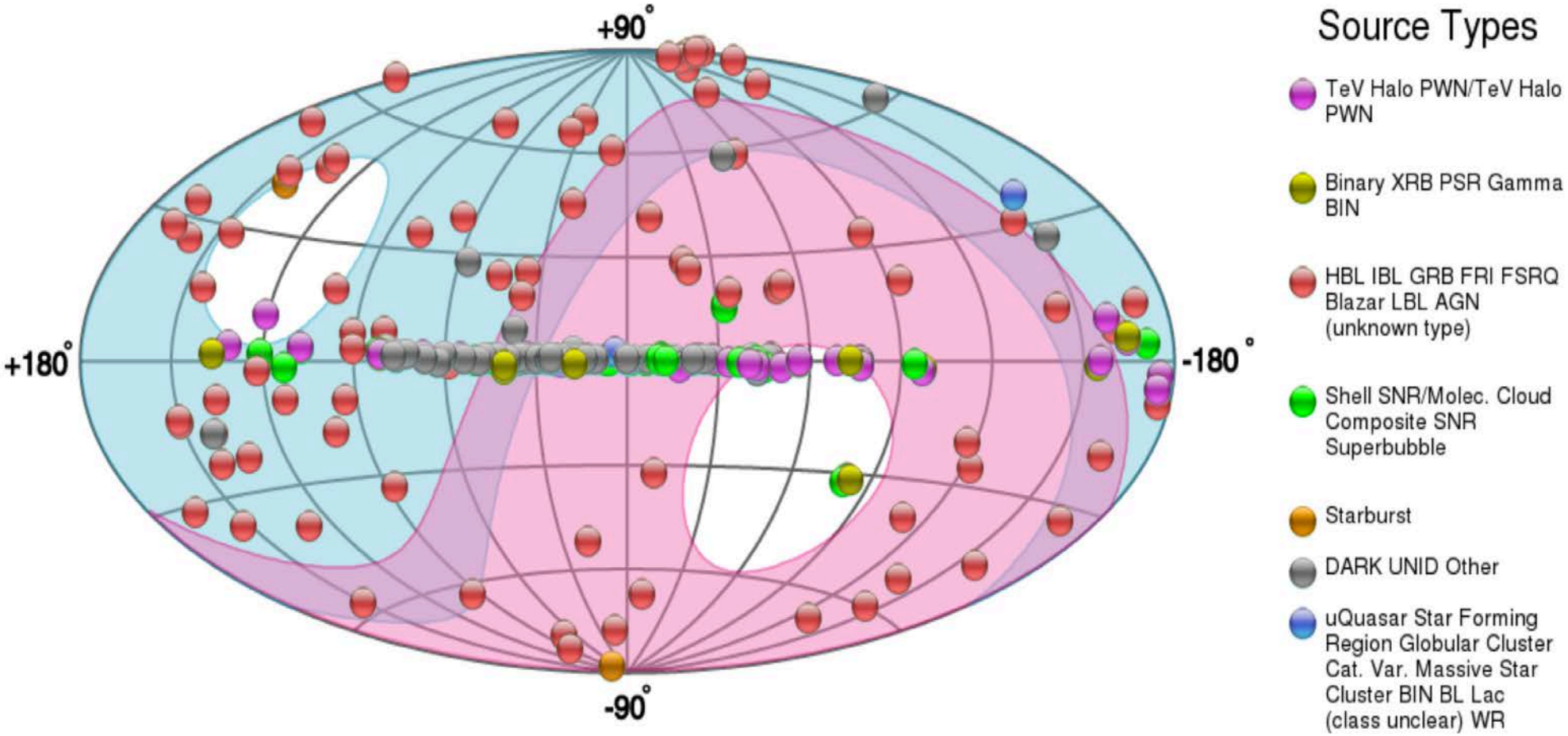
Shower development



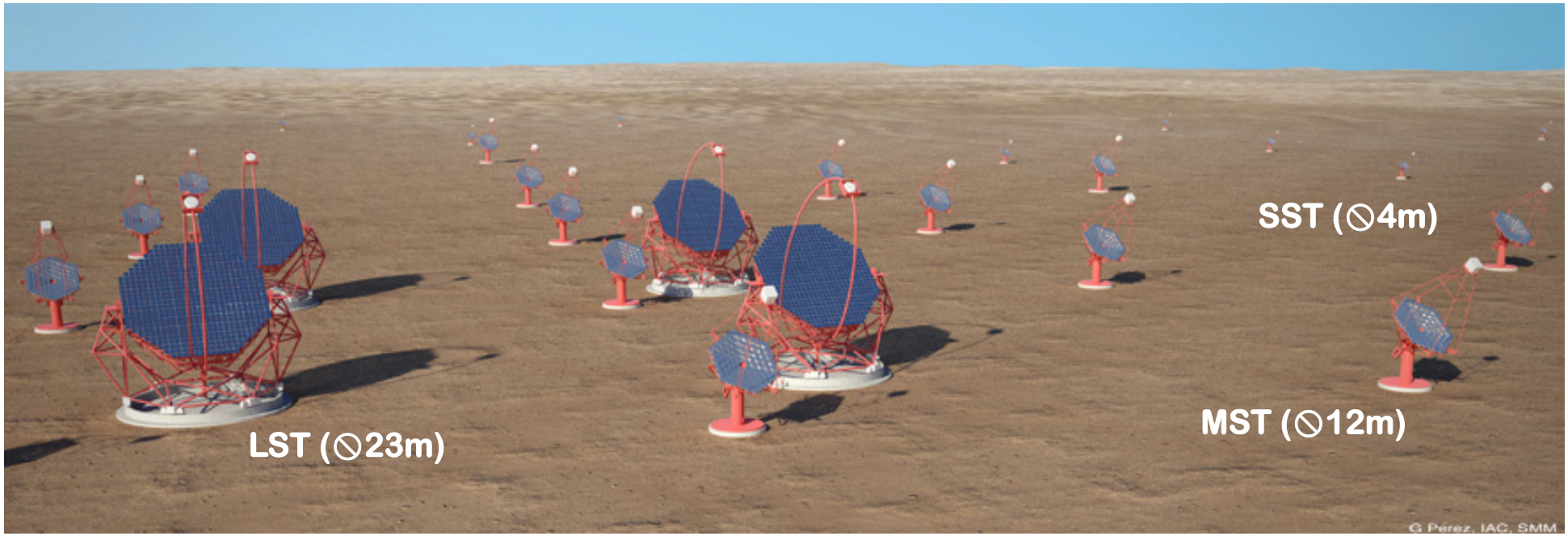
Rossi "Approximation B"

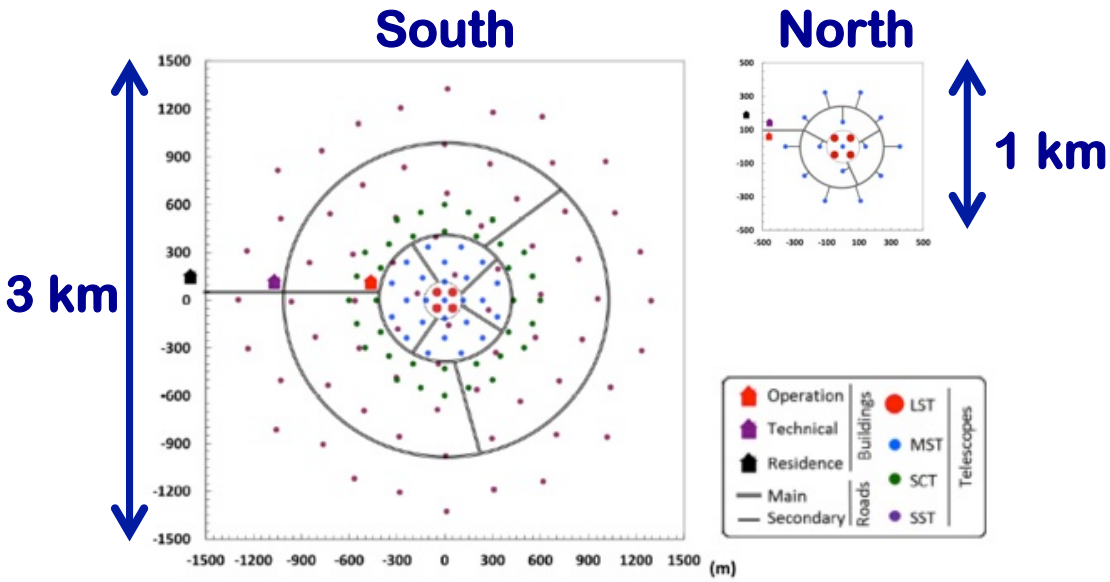
Peak of shower t_{max}	$1.0 \times (\ln y - 0.5)$
Center of gravity t_{med}	$t_{max} + 1.7$
Number of e^+ and e^- at peak	$0.3y/\sqrt{\ln y - 0.31}$

Last 20 years: success of Cherenkov astrophysics

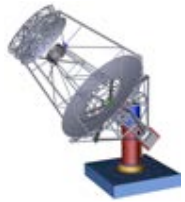


The future of Cherenkov detectors: CTA





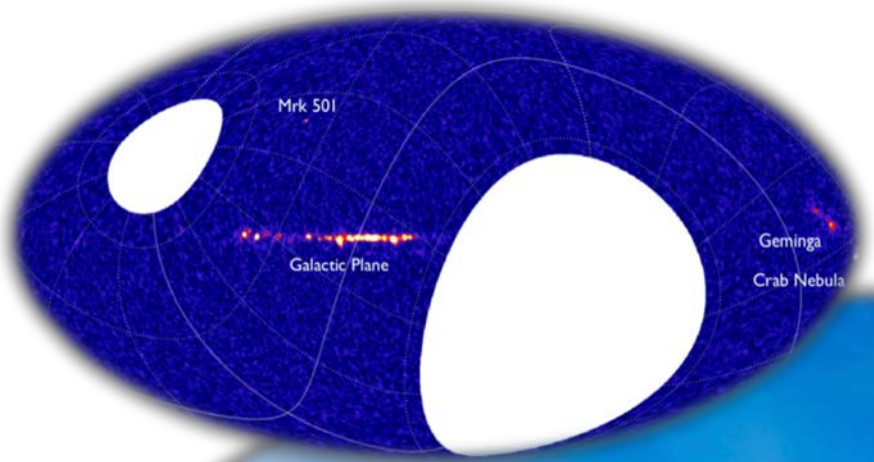
SCT (⦸10m)



Characteristics

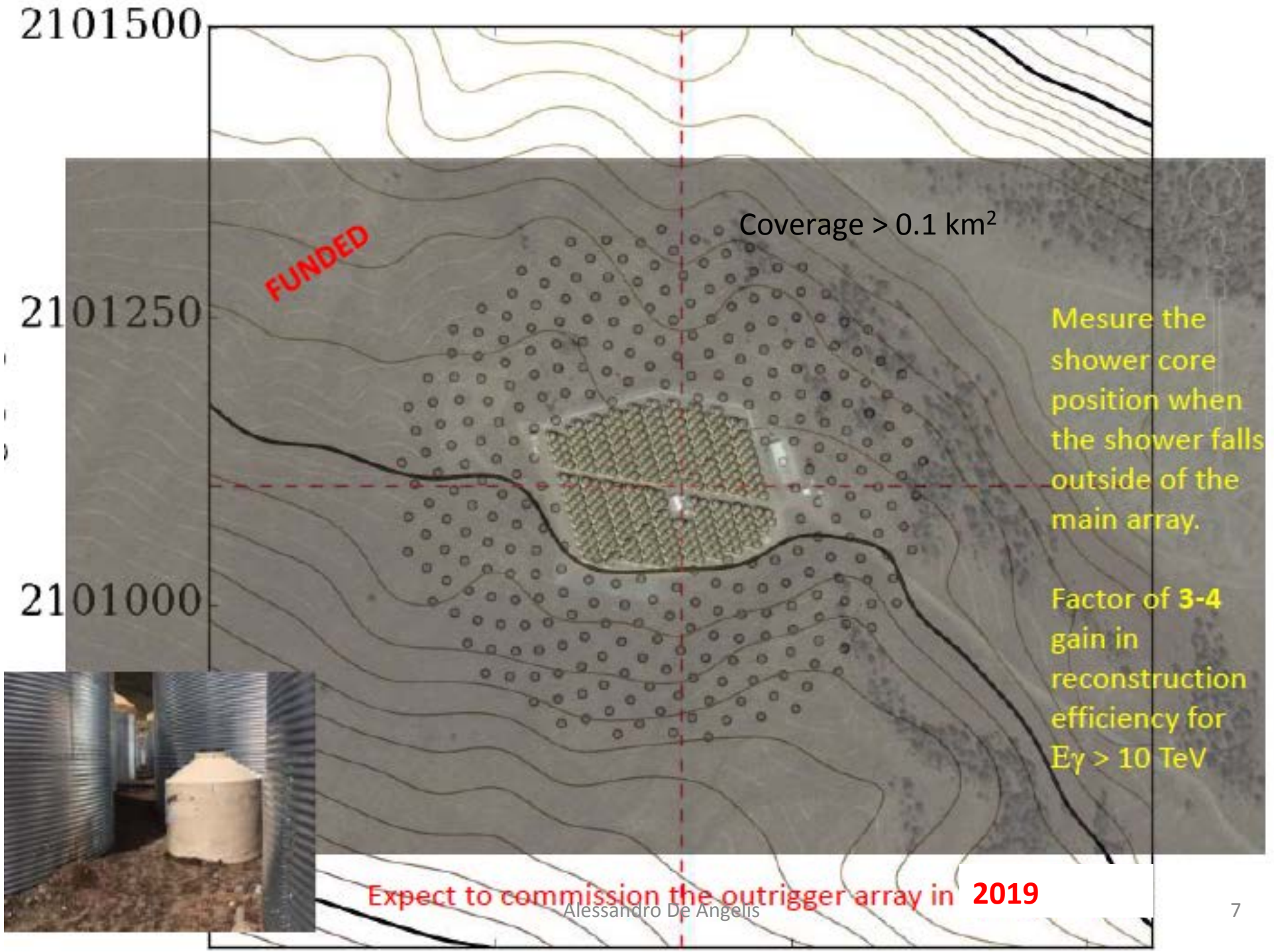
2 sites (north & south)
3 telescope size classes
About 120 telescopes in total

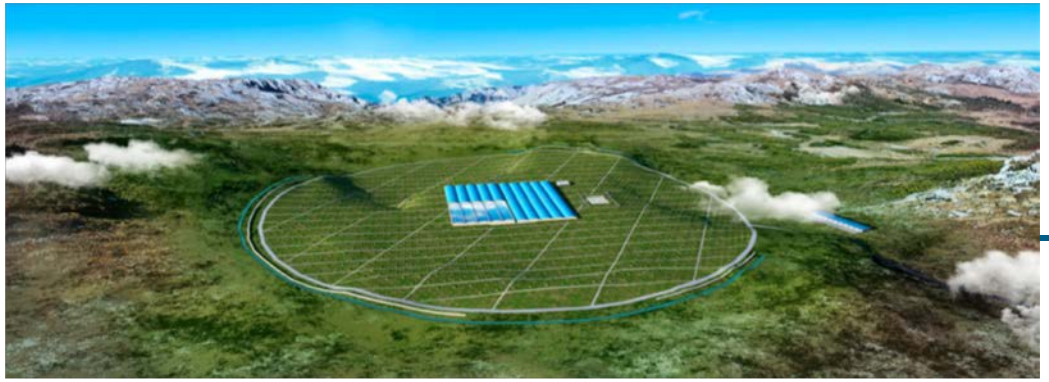
Still a strong science case for EAS: serendipity: transients/GRBs, …



EAS design: HAWC in Mexico
Smaller sensitivity/unit time
Larger FoV & exposure

4.2 km asl

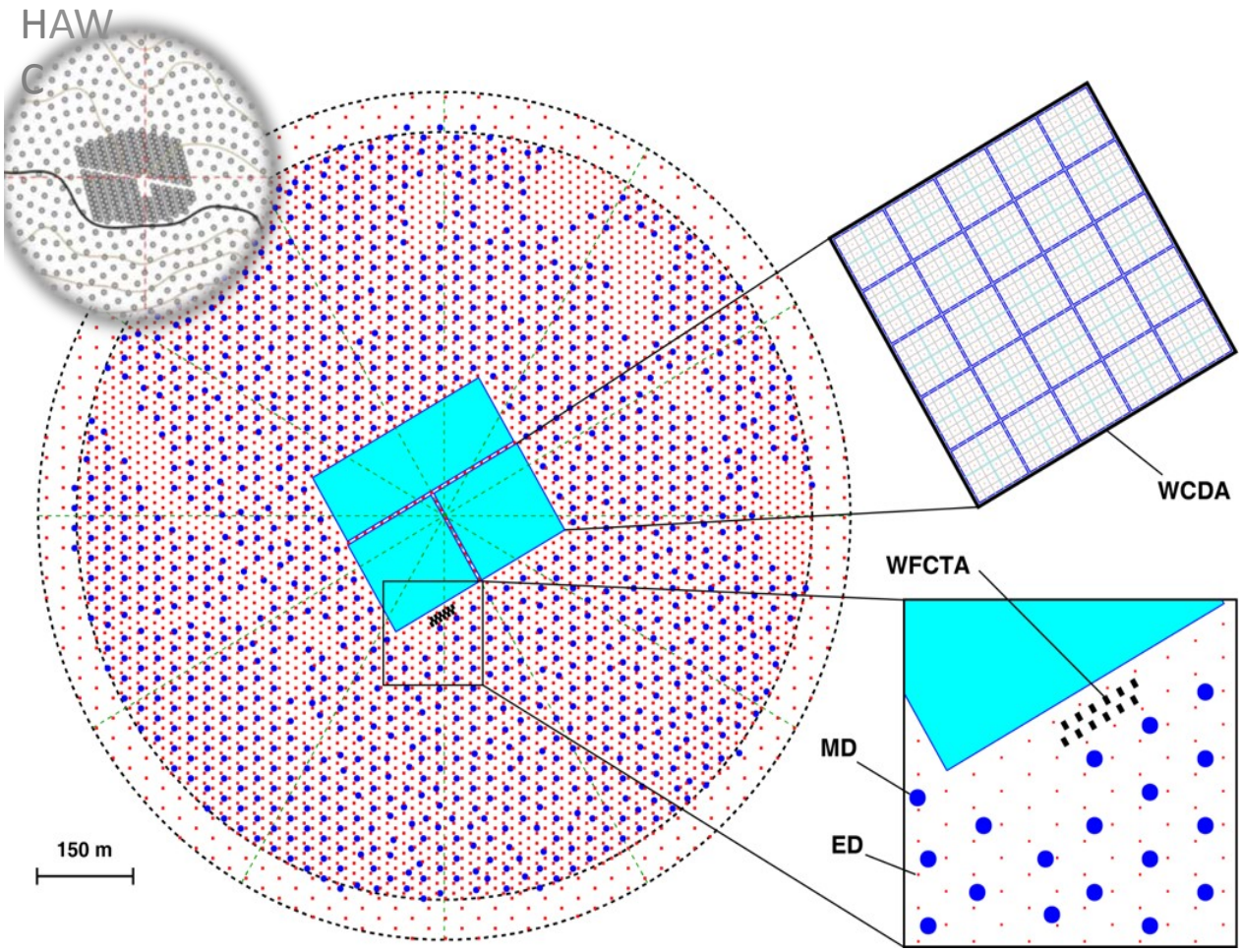

2101500
2101250
2101000
FUNDED
Coverage > 0.1 km²
Mesure the shower core position when the shower falls outside of the main array.
Factor of 3-4 gain in reconstruction efficiency for Eγ > 10 TeV
Expect to commission the outrigger array in 2019



LHAASO

Sichuan, China, 4410 m asl

25% ready in 2020



5195 Scintillators

- 1 m^2 each
- 15 m spacing

1171 Muon Detectors

- 36 m^2 each
- 30 m spacing

3000 Water Cherenkov Cells

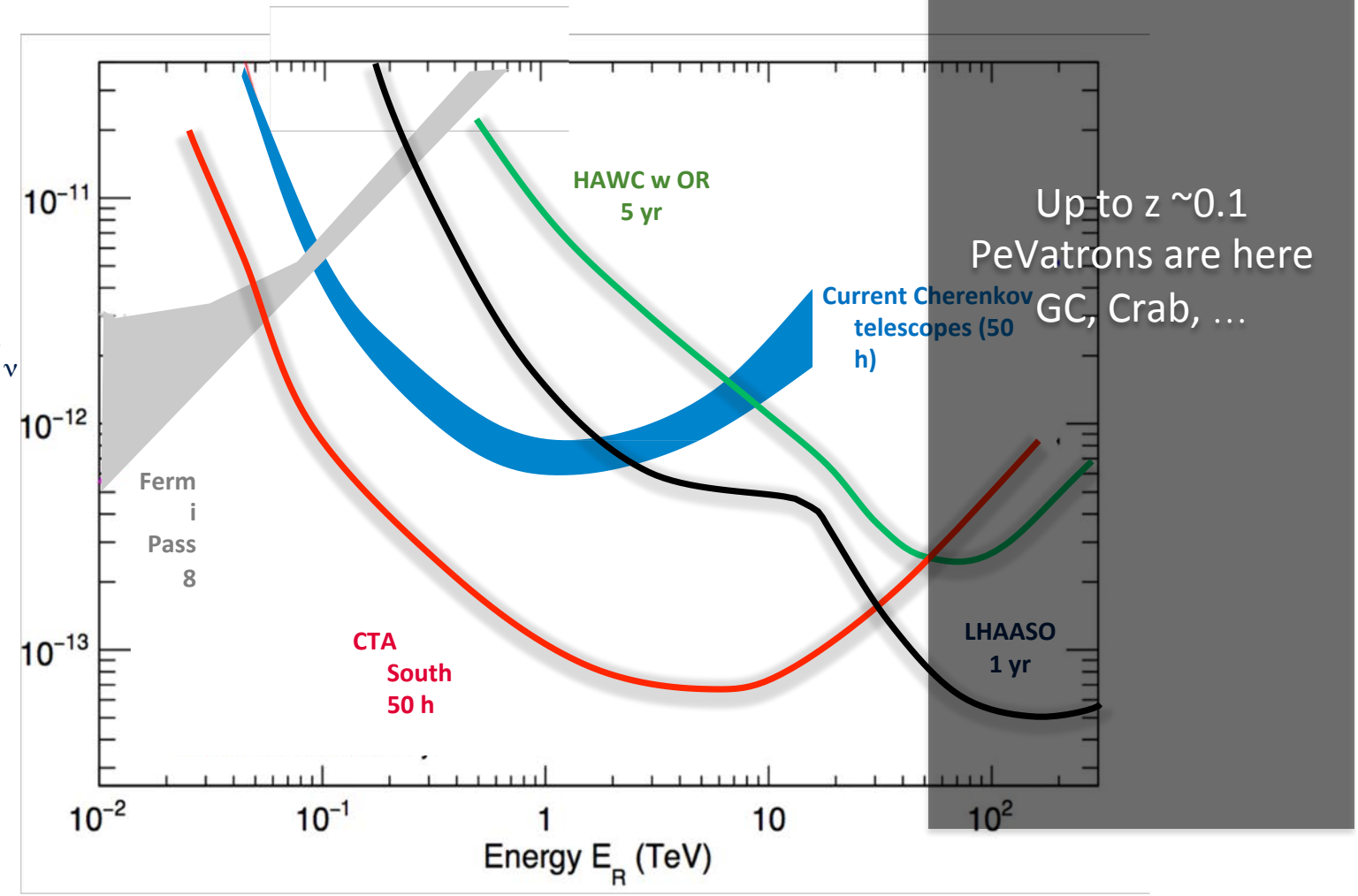
- 25 m^2 each

12 Wide Field Cherenkov Telescopes

¼ ready in 2020

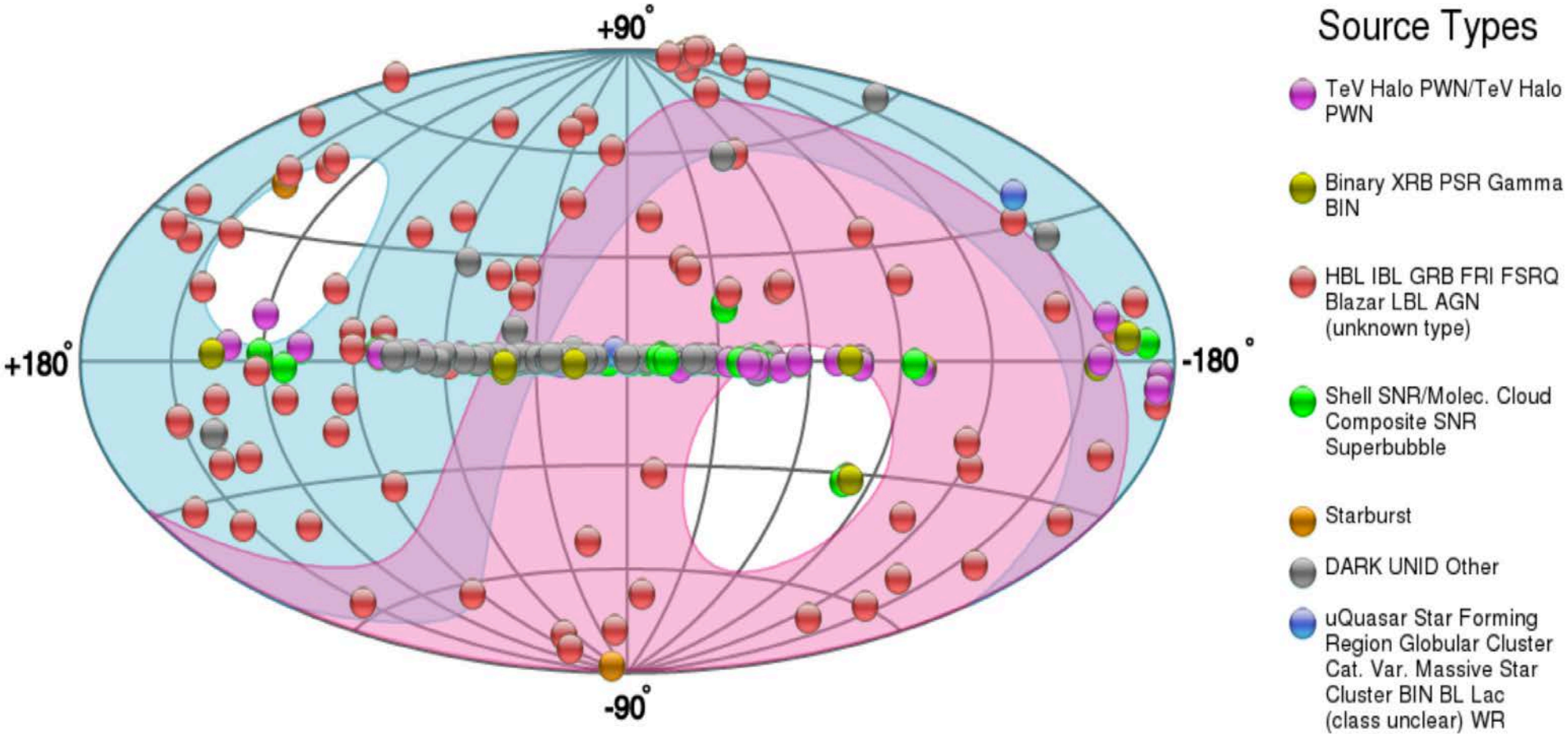
	IACT Arrays	Ground-particle Arrays
Field of view	3°–10°	90°
Duty cycle	10%–30%	>95%
Energy range	30 GeV – >100 TeV	∼500 GeV – >100 TeV
Angular resolution	0.05°–0.02°	0.4°–0.1°
Energy resolution	∼7%	60%–20%
Background rejection	>95%	90%–99.8%

SENSITIVITY (STEADY SOURCES)



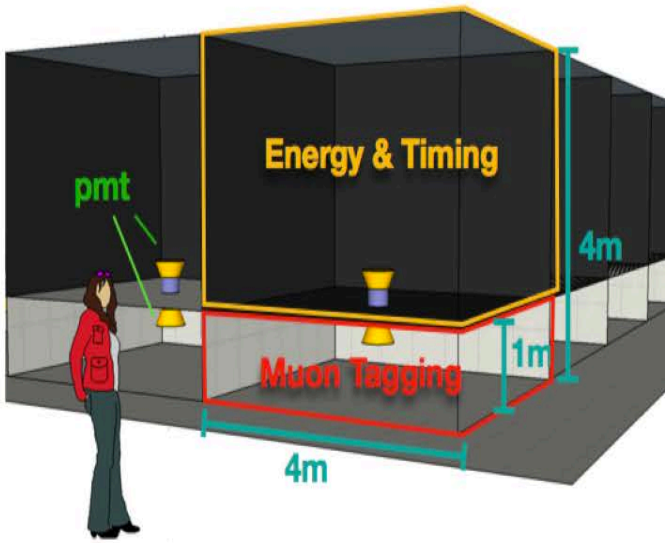
From W. Hofmann

HAWC+, LHAASO funded, but there is a strong case for a **wide-field experiment in the Southern hemisphere**

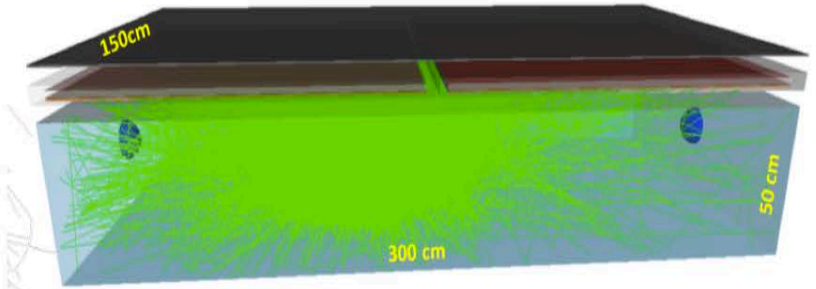


Several different proposals
GROUPS RECENTLY CONVERGED
to a common R&D group

(from Heidelberg Meeting in October 2018)



LATTES STATION



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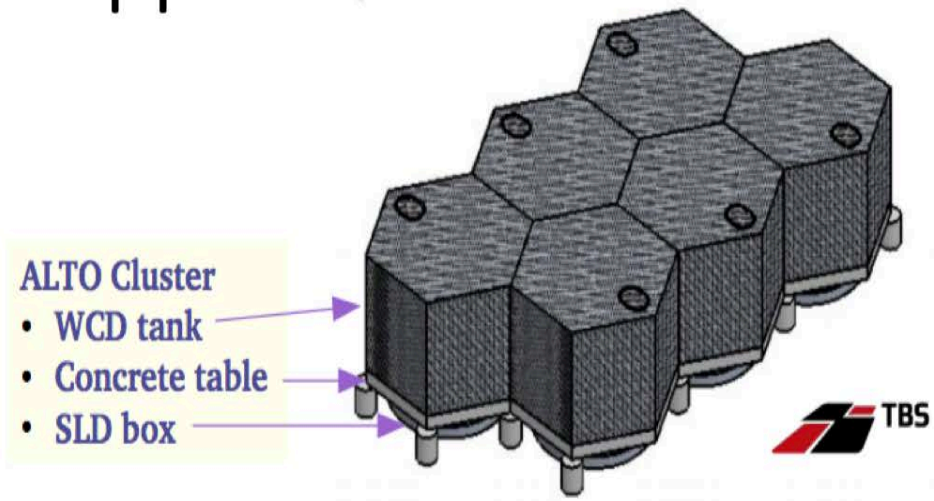
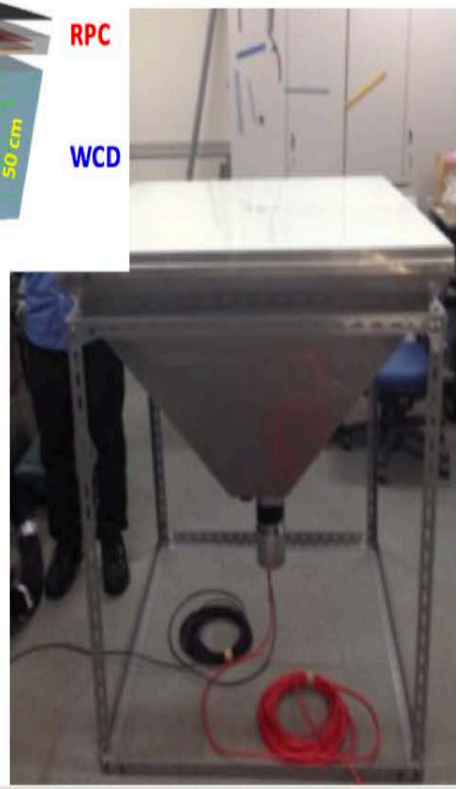


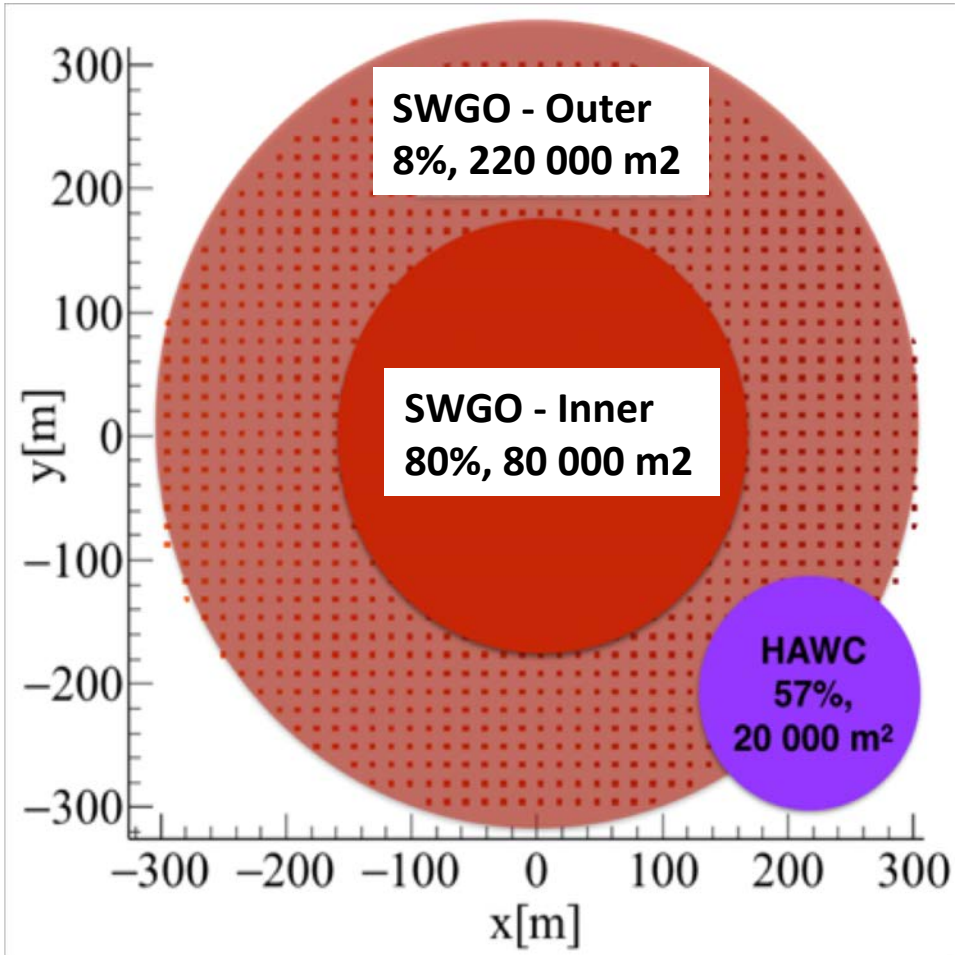


- "Southern Wide-field Gamma-ray Observatory R&D"
- 3 year programme to come to a recommendation on the design and site of a wide field gamma-ray observatory in the southern hemisphere
- Observatory concept
  - Ground-particle detection based high altitude gamma-ray observatory – 100% duty cycle, steradian FoV, latitude -15° to -30°
  - Wide energy range 100s of GeV to 100s of TeV
  - High fill-factor core detector with area considerably larger than HAWC and significantly better sensitivity, with a low density outer array
    - With possibility of extensions or enhancements
  - Based primarily on water Cherenkov detector units
  - Modular and scalable

Price Target: ~40-50 MEUR

SWGO: a world-based project for the R&D of the Southern Wide-field Gamma-ray Observatory

- A 3-year project starting on July 1st, 2019
- Signed by Parties in Argentina, Brazil, Czech Republic, Germany, Italy, Mexico, Portugal, UK, US (+ groups from Chile, China, France, Japan, Slovenia, Spain, Sweden, Peru)
- Italy: INAF + University Consortium (BA, CT, PD, PG, PoliMI, RM2, SI, TO, TS, UD)



The Steering Committee

- Argentina: Adrian Rovero (IAFE)
- Brazil: Ron Shellard (CBPF)
- Czech Republic: Jakub Vicha (Academy of Sciences)
- Germany: Jim Hinton (MPI-K Heidelberg)
- INAF: Marco Tavani (IASF Roma)
- Italy University Consortium: Alessandro De Angelis (Padova)
- Mexico: Andres Sandoval (UNAM)
- Portugal: Mario Pimenta (LIP Lisboa)
- UK: Paula Chadwick (Durham)
- US: Petra Huentemeyer (Michigan Tech)

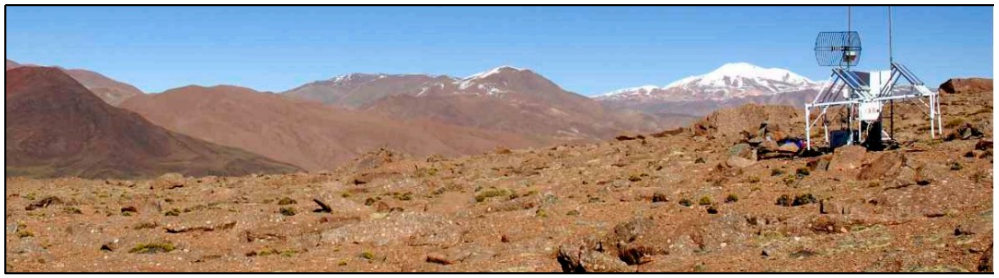
ITALIAN GROUPS:

- *Torino: Andrea Chiavassa, …*
- *Padova: Michele Doro, Ruben Lopez-Coto, Cedric Perennes, …*
- *…*

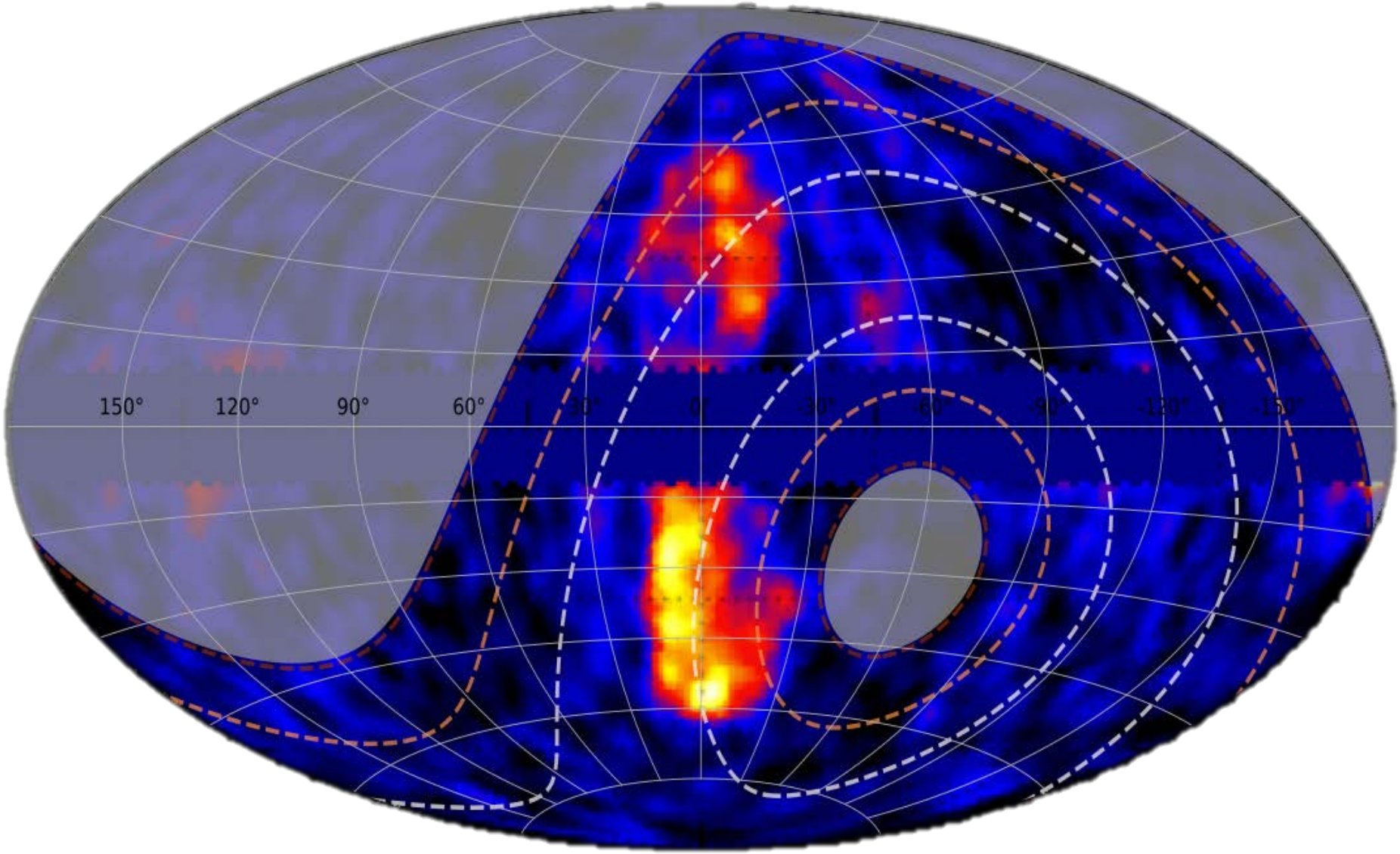
Site Considerations

- Host country
  - Legal, political, economic, security, …
  - Local partners
- Local Infrastructure
  - Road access, water access, power, network
- Altitude
  - >4.5 km
- Longitude
  - Not much choice given high altitude
- Latitude

Sites in Argentina, (Bolivia), Chile, Peru




Caribbean Sea
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
VENEZUELA
COLOMBIA
ECUADOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY
GUYANA
SURINAME
Caracas
Bogotá
Quito
Lima
Brasília
Asunción
Santiago
Buenos Aires
Montevideo
Laguna Sibinacocha, Peru
4.9 km
ALPACA site near Mt Chacaltaya, Bolivia
4.7 km
CUBIC site, Salta, Argentina
4.8 km
Chajnantor region, Chile
5.0 km
Scale 1:35,000,000
Azimuthal Equal-Area Projection

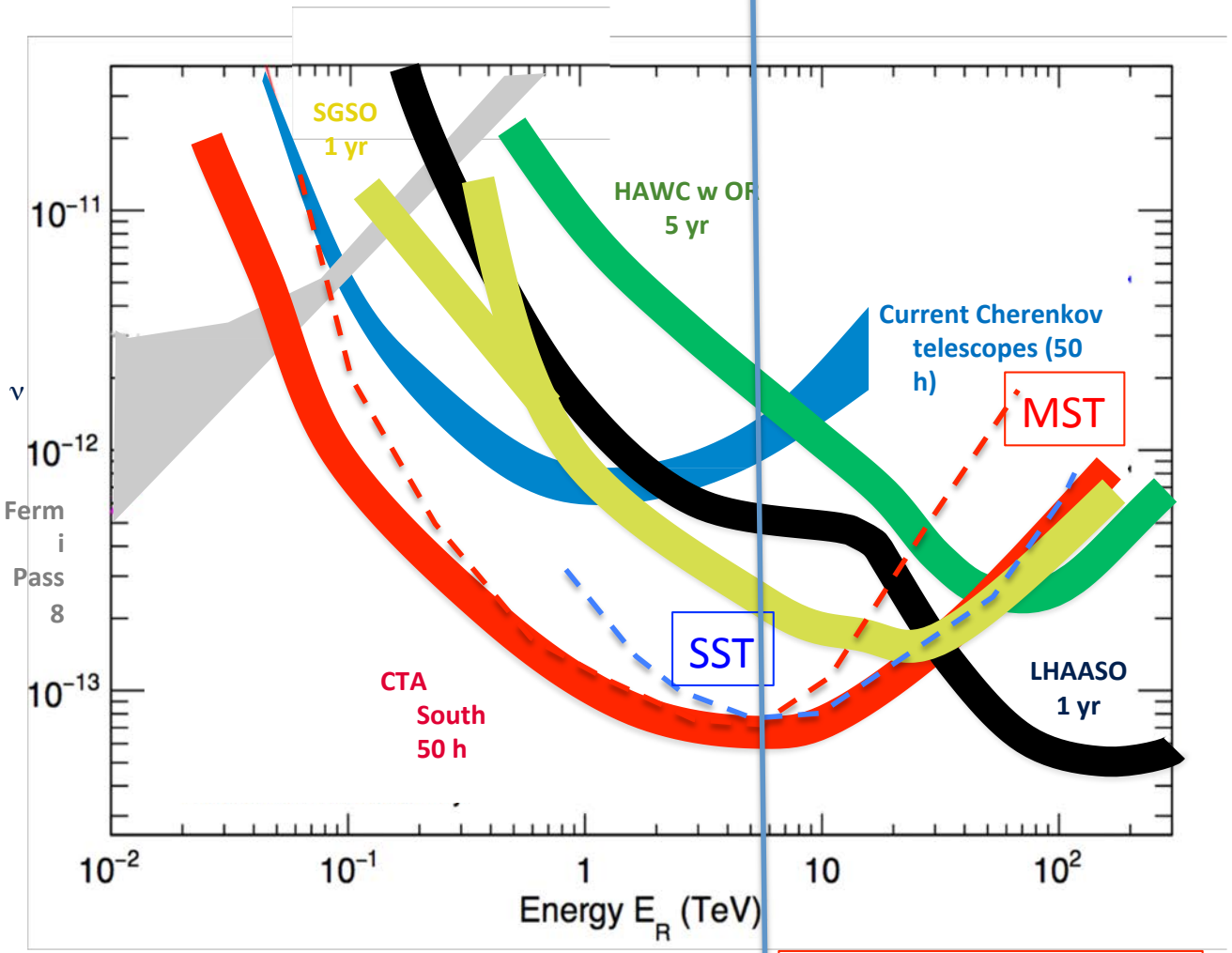

150°
120°
90°
60°
30°
0°
-30°
-60°
-90°
-120°
-150°

Some criteria for evaluating performance

- Sensitivity
  - Stable sources
  - Transients
- Space resolution
- *Exposure (with some caveats)*
- Energy resolution

SENSITIVITY (STABLE SOURCES)

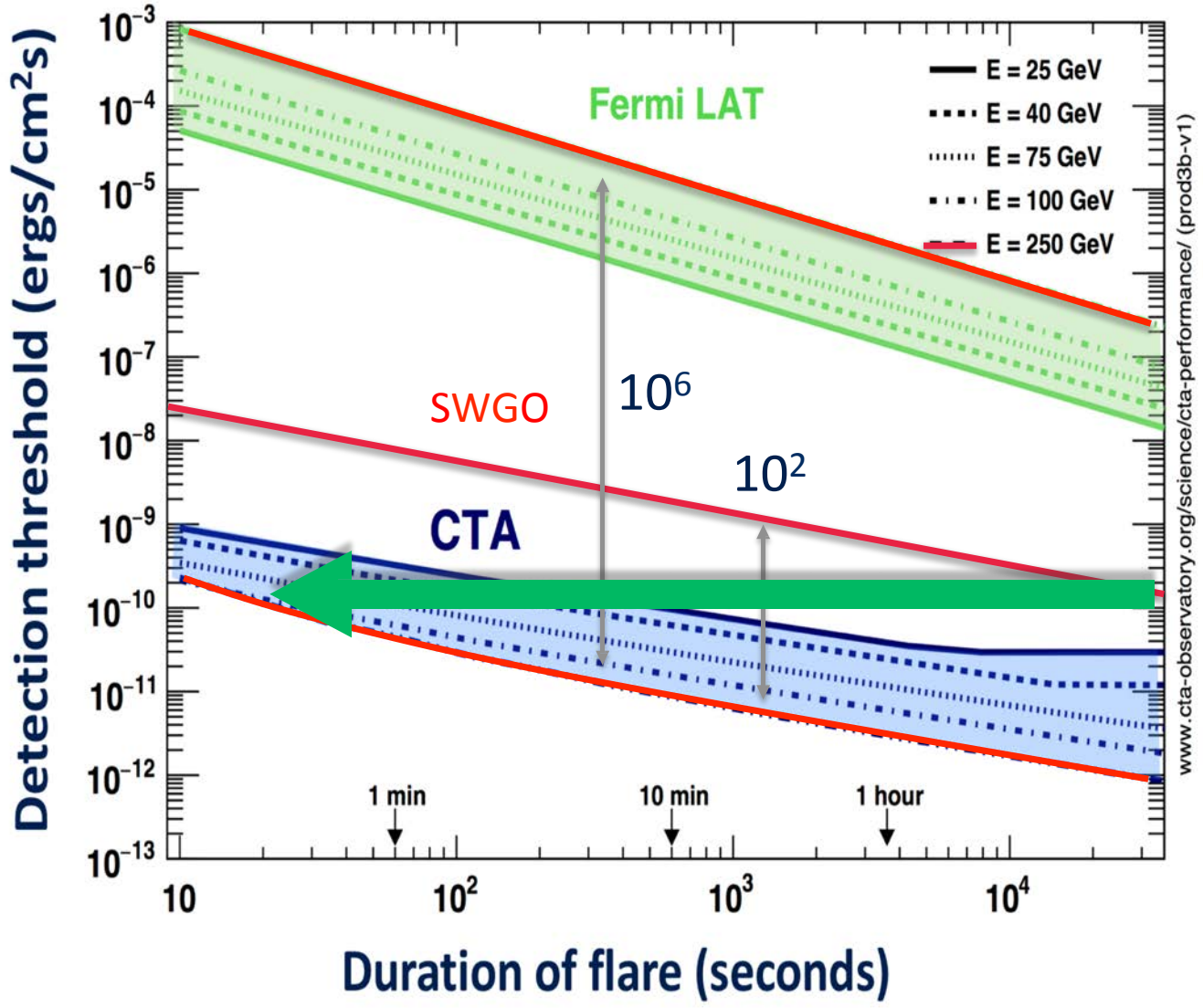
$E^2dN/dE = \nu F$
[erg/cm^{2}s]

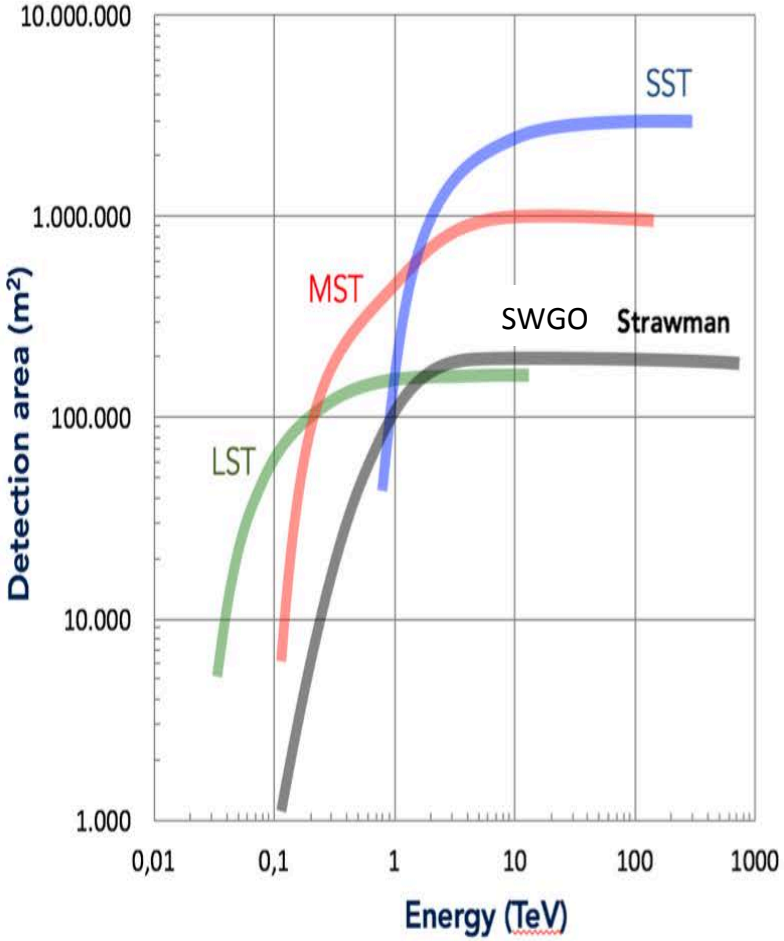


From W. Hofmann
+ A. De Angelis

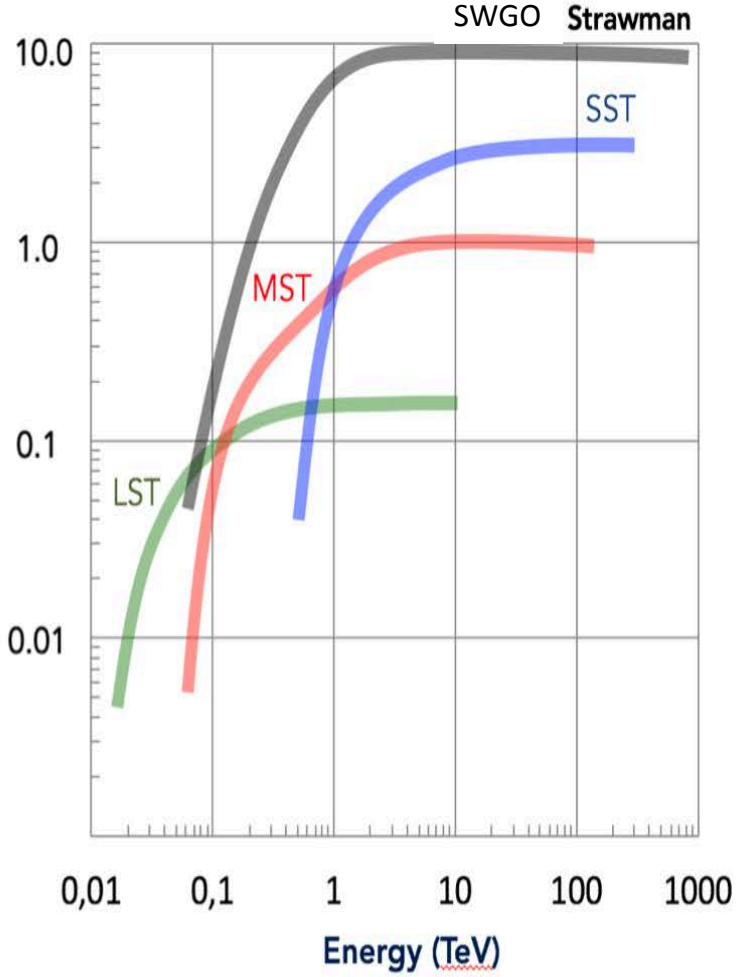
Crossover at ~ 5 TeV

THE LOW ENERGY CASE: TRANSIENTS





Detection Area



Annual Exposure

- Transients: If CTA can get there → it is much better
- Steady sources: If background can be suppressed → can do much better than CTA over several years

THE HIGH ENERGY CASE: SENSITIVITY **(>~5 TeV)?**

- The problem is: how many photons do we observe?
- From Crab

$$\frac{dN_\gamma}{dE} \simeq 3.23 \times 10^{-7} \left(\frac{E}{\mathrm{TeV}}\right)^{-2.47-0.24\left(\frac{E}{\mathrm{TeV}}\right)} \mathrm{TeV}^{-1}\mathrm{s}^{-1}\mathrm{m}^{-2}$$

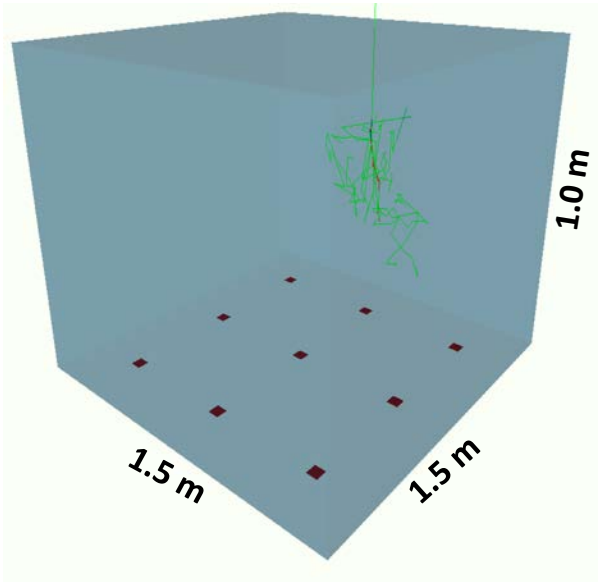
(FLARE) SENSITIVITY **(>~5 TeV)? PeVatrons?**

- Above 5 TeV, from 1 Crab you have only ~3 photons/km^2/h
  - Time threshold for SST from 1 Crab is ~1.2h
    - Even with 100 h, ~2000 photons
  - Time threshold for SWGO from 1 Crab is ~24h
    - ~100 photons in 100h

- BUT in CTA the MSTs dictate the threshold!!!
  - From 1 to 5 TeV, from 1 Crab you have ~600 photons/km^2/h
    - Time threshold for MST from 1 Crab is ~3 min
    - Time threshold for SWGO from 1 Crab is ~1h

  - CONCLUSION:
    - Steady sources: SWGO sensitivity better than CTA (space domain irrelevant)
      - SSTs can be used for imaging only for sources at Crab
    - Transients in PeVatron physics at CTA will be dominated by the MST
    - Energy resolution better for the SSTs. But how many points > 5 TeV?

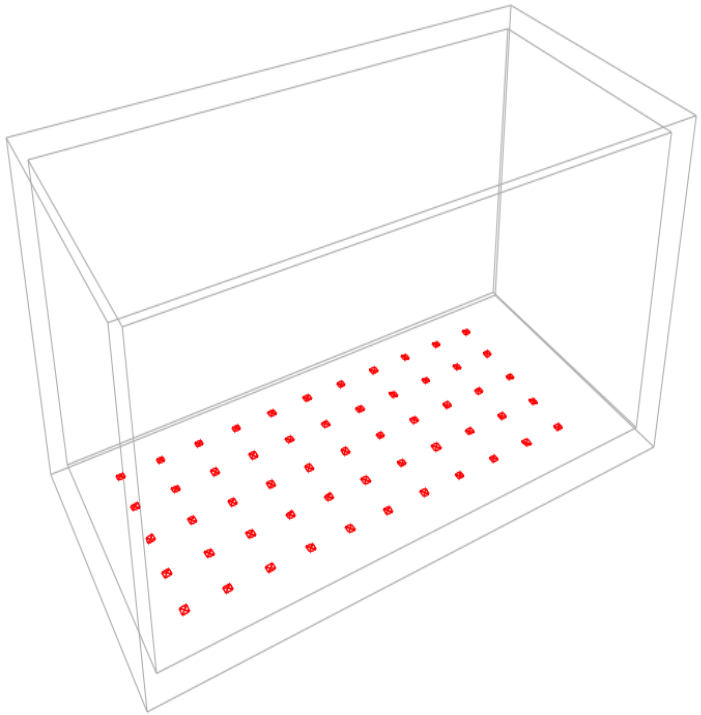
Work in Padova: optimization of photosensors location/size/kind



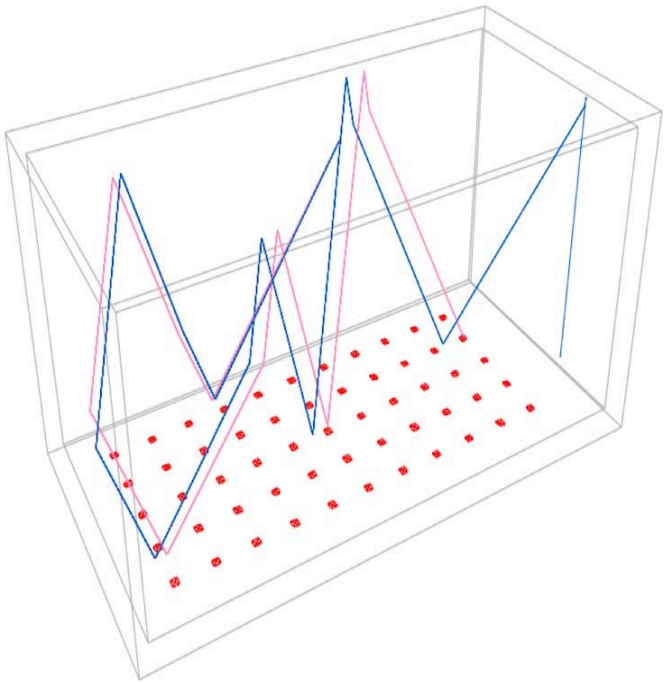
1. At 5000 m asl, tall tanks might be unpractical
2. We aim at lowering the energy threshold <1 TeV

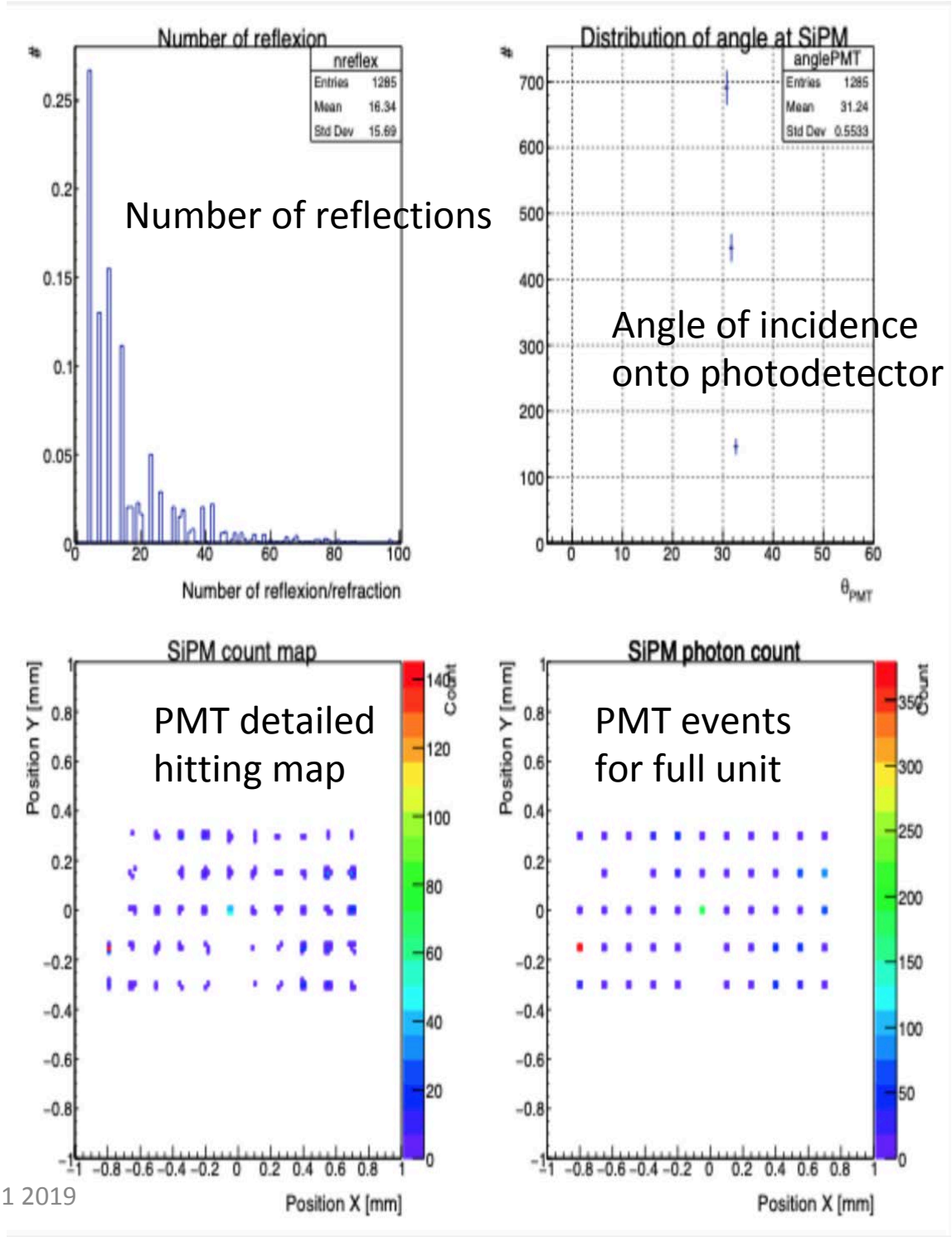
- Design criteria
  - Inner walls covered with white diffusing Tyvek to enhance signal (80% diffuse, 2% reflected)
  - Access to Cherenkov time distribution
  - Image the WCD signal
    - Many photosensors

Simulation in Padova



- Cedric Perennes, Michele Doro + LIP Lisboa are developing simulation with
  - optical raytracing with open-source ROBAST code
  - Physical with GEANT4 (Lattesim→Common code)





- Imaging from this seem feasible
  - Direction ☺
  - Energy deposited 😐
  - Particle type 😐

SWGO in summary

- A 3-years R&D project on an EAS in South America will start on July 1st; with a target cost of ~40-50 MEUR, it involves a wide community

- Some of the scientific highlights, complementary to CTA, are clear
  - E > 5 TeV, stable sources
  - Transients in the multimessenger era
  - Diffuse sources at VHE
  - The unexpected (serendipity)

  - Can the EAS threshold be lowered to 100s GeV?

- The role of politics (observatories, ERIC/ESO vs. US+MoUs, etc.) can be relevant

- 1st General Meeting in Padova, October 30/31 – Everybody welcome, also to subscribe in Working Groups:
  - Science case development
  - Simulations, analysis and array optimization
  - Candidate site evaluation
  - Detector design development
  - Outreach